# I like to Move it: Investigating the Effect of Head and Body Movement of Avatars in VR on User's Perception

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### Abstract

Interacting with computer generated humans in virtual reality is becoming more popular with the current increase in accessibility of virtual reality head mounted displays and applications. However, simulating accurate behavior in computer generated humans remains a challenge. In this study, we tested the effects of full body behavior (Body Movement and Head Movement) in terms of viewers perception (comfortability with and realism of the computer generated human) using an animated computer generated human in virtual reality. Our findings imply the significant influence of body animation (excluding head animation) on both comfortability and realism of the computer generated human. 37.5% of the participants did not notice the exclusion of the head animation; implying the importance of body animations over head animations. Using the results, we derive guidelines on computer generated human design and realization as well as their influence on the viewer's perception. Finally, we discuss the constraints that should be taken into account when animating in virtual reality.

### Author Keywords

virtual reality; realism; comfortability; uncanny valley

### ACM Classification Keywords

H.5.2 [Information interfaces and presentation (e.g., HCI)]: Miscellaneous

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### Animations:

- HMBM Head Movement and Body Movement. This animation included full body movement without exclusion of any body parts.
- HM'BM Non Head Movement and Body Movement. This animation included upper and lower body movement and excluded head movement.
- HMBM' Head Movement and Non Body Movement. This animation included head movement and excluded the upper and lower body movement.
- HM'BM' Idle animation. This animation excluded all motion from any body part.

## Introduction and Background

Virtual reality (VR) is becoming more accessible everyday resulting in a diverse set of applications [5, 2, 1]. Designers and developers already developed insights on how to build VR applications. However, an ongoing core challenge of VR is representing people. Previous work shows the importance of virtual body representation as it increases the level of immersion by providing a "familiar interface" for the users to interact with the virtual world [11, 13] or with one another. This allows users to interact with one another or with different computer generated (CG) non-player character (NPC) seamlessly.

Although there has been a significant development in CG characters' realism and quality. The main struggle rises from the viewer's reaction rather than the technological capability of achieving realism. Researchers [6],investigated the effect of realism on presence. They noted that the more realistic characters became the more they became eerie and caused a level of discomfort in the audience. This feeling of discomfort is connected to the "Uncanny Valley" [8]. The uncanny valley occurs when a high level of realism is achieved in CG characters that causes viewers to be repulsed by them [7].

MacDorman [7] explains the uncanny valley as a "Dimension of Variation". This theory suggests that interactivity, form, and dynamics of the CG character, are all factors in the believability of the CG character. However, it is unclear as to which parts of the body would have a positive significant impact on the viewer's perception of the CG character. Qiao [9] explored the effect of head animations including facial expressions, head movement, and eye movement on viewer's perception. Their results implied significant influence over believability by the inclusion of head movement to the CG character. On the other hand, facial expressions had a negative effect. These results suggest that different body part animations influence user's perceptions differently. However, this work was conducted on flat screens.

In this paper, we aim to explore the influence of head and body movement on comfortability and realism of characters in VR setups rather than flat screens. In a study assessing body movement in VR, participants expressed a stronger sense of presence. This makes body movement in VR an essential element for user immersion during a VR session. We advance the state-of-the-art of perceiving CG in VR through the following contributions:

- We hypothesize that head and body movement differently influence viewer's perception.
- We demonstrate the validity of our hypothesis through a user study, showing that exclusion of either the head and/or the body animation differently affect viewer's perception.

# Head and Body Movement in VR

Research on verbal and nonverbal communication between humans suggest the importance of body movement as a sort of communication. Studies explored the effect of our perception with regards to facial expressions, words, and body movement (body language). Posture, and body language were essential for adding value for perception [4]. With body movement being a factor in human perception in real life; we would like to test if body movement would have similar effects in a virtual world by using CG humans. In this work we focus on the following research question:

1. Does Head and Body Movement of Avatars Influence User Perception of Realism and Comfortability ?

# Маіе Fende Fende Fende Galance Gala

**Figure 1:** The different Computer generated characters with their respective animation types.

### Design

To test our hypothesis of the influence of head and body movement on realism and comfortability, we conducted a user study. We recorded the participants' ratings for realism and comfortability while viewing avatars with combination of different animations. The independent variables included: gender, head movement and body movement.

We created the 4 different combinations of the animations to be our conditions. We applied a repeated-measures design. The full body animation was divided into two separate animations, body animations (upper and lower body animations such as hands, legs, and torso) and head animations (head movement in reference to the body motion, no facial expressions were included).

We measured the comfortability of the participants as well as their perception on the realism of the behavior of the characters in front of them. Participants answered a quantitative questionnaire about their experience.

### Stimuli

CG humans were used from Mixamo<sup>1</sup>. In order to overcome gender-based influence on the perception as reported in [10], we created and used two characters(male and a female). Both characters were animated using Mixamo's "arguing" animation. The animation included full body movement (head, lower-body, and upper-body). There were no animations for facial expressions or lip sync in those animations.

### Apparatus and Tasks

Our apparatus consist of a HTC Vive. A VR application was developed using Unity3D game engine. The application was running on a Windows laptop.

<sup>1</sup>urlhttps://www.mixamo.com

Participants were playing as detectives in a world with "body snatchers" <sup>2</sup>. Participants were to investigate two cases of murder. In one case the suspect was a female, and in the other the suspect was a male. Each case had 4 suspects with "body snatchers" amongst them. Participants were asked to identify the humans from the snatchers. The two animated male and females were used as the suspects with each suspect animated using one of the animation combinations. The order of appearance was counterbalanced using a Latin Square. They were asked which body part they thought was not animating; choosing from a multiple choice question that included, head, body, neither, or both. At the end of the experiment the participants were asked to choose the real people from the 4 individuals.

### Measures

A post-test questionnaire was used after interaction with each CG character. Users would put on the headset, interact with one character then remove the headset, take the questionnaire and move to the next character. This decision was based on the disadvantage that post-test have as they rely on the memory of the users and it could lead to errors.

After each interaction they would answer a questionnaire about the realism and comfortability of each character using a 5-point Likert scale.

### Participants & Procedure

We recruited 24 participants(12 males and 12 females). With an age range of 15-25 years old. Three of the participants had previous VR experiences with at least one type of VR HMD, others didn't have any VR experience. Most participants were exposed to CG characters before through video games or films.

<sup>&</sup>lt;sup>2</sup>"body snatchers" are aliens that can shape shift into humans



**Figure 2:** Comfortability of all animation combinations for male, female, and their average.



**Figure 3:** Perceived realism of all animation combinations for male, female, and their average.

After welcoming the participants we asked them to fill in the demographics and sign the consent form. We presented VR headset and explained the game and the procedure of the study. After viewing a character, they had to identify the moving body parts. After viewing all characters, we asked the participant to identify the human from the snatcher to reflect the realism of the character. We had this task to ensure the engagement of the participants with the presented character, hence we didn't consider the participants response in this work.

### Results

On average, participants spent 24 minutes (SD = 5.7 min) in VR (3 minutes with each animation). We analyzed the ratings from the participants after viewing all 4 animations. Since our participants' ratings are non-parametric data, we used ART-Tools<sup>3</sup> by Wobbrock et al. [12] to conduct a repeated measured two-way ANOVA with the within-subject variables body and head using participant as a random factor.

The main effect of body was significant, F(1,23) = 5.348, p = .030, the main effect of head not F(1,23) = 1.192, p = .286. Furthermore, we found a significant interaction of body×head, F(1,23) = 26.841, p < .001 on the perceived realism and comfortability.

We were also interested in the effect of gender. Therefore, we conducted a three-way ANOVA with the variables body, head, and gender. Again, we found a significant effect of body, F(1,161) = 1.546, p < .001, and an significant interaction of body×head, F(1,161) = 3.496, p < .001. There were no further main effects or interactions (all with p > .05).

In summary, our findings implies that different body part animations influence the realism and comfortability perceived by the viewer. Significant difference was found, in terms of realism, when any animation from the body part was removed. There were no significant differences between HM'BM and HMBM' (not animating the head versus not animating the body).

The case was similar with comfortability. However, there were no significant differences between the HM'BM' and the HMBM animations, which implies that the two shared similar comfortability effect on the participants. Moreover, there was significant difference between the HM'BM' and HM'BM, with participants more comfortable with HM'BM' (idle animations) than the HM'BM animations, where the head was moving however the body was still. There were no significant differences between HMBM' and HM'BM'.

Concerning the gender influence, using two(male and female) CG Characters, we found no significant effect on CG gender on perceived realism or comfortability of characters as depicted in Figure 3. Moreover, we analyzed the responses of the participants concerning identifying the animating body parts. We found out that, 37.5% did not notice that the head animation was absent while observing the HM'BM animation. The results suggest the importance of upper and lower body animation's importance over the head animation when it comes to viewer's comfortability.

### Discussion

Informed by previous work, we hypothesis that different body movements influence the comfortability of the audience and perceived realism of CG characters in a VR setup.

Our results implies different perceptions in body movement and head movement. Body movement had a significant

<sup>&</sup>lt;sup>3</sup>ART-Tools: https://cran.r-project.org/web/packages/ARTool/

effect on perceived realism of characters as well as audience comfortability. However, head movement did not show significant effect on perception. We also found a significant interaction between body and head movement. Earlier Studies imply the importance of body posture and body language in communication in human to human interaction [4]. With VR providing users with seamless movement with a first person perspective; it is expected that users would interact with other humans in VR similarly to real life. Qiao's [9] findings from the flat screen reflected the importance of the head movement, on the other hand VR allowed the users to be "present" [3] with the CG character. Our findings reflects the importance of including the body part animation in VR setups, where participants can view the entire avatar in VR rather then a flat screen. This made users investigate the entire body behavior rather than just the head.

Our findings reflects the implication for designers, where We highlight the importance and the need to focus animation efforts on body animations than the head movement when dealing with humanoid avatars in a virtual experience.

### **Conclusion and Future Work**

In this paper, we investigated how different body movements influence the comfortability of the audience and perceived realism of CG characters in a VR setup. Our findings support our hypothesis that CG characters body animations have an effect on audience perception of realism.

We conducted a user study where participants investigated the behavior of 8 different CG characters (4 males and 4 females). Where each CG character animated different parts of the body. In this study we explored body(upper and lower) movement and head movement. Participants were asked to rate CG characters based on how realistic they perceived them as well as how comfortable they were around them. We reflect the importance of body animation on perception. When having a CG character in VR, focus on body animations and language are important to create a more familiar or comfortable feel than head animation.

Our findings extend previous work of Qiao [9]. They reported the importance of head animations in an avatar. Our study highlights that as much as the head animation could have influence on the avatar, body animations has a bigger influence as opposed to head animations. In this study we did not explore the difference between perception of a CG character in VR vs a flat screen. Future studies should try to investigate the existence of a difference.

Facial animations and further detailed animations were not tested in this study. Future research should investigate the effect of facial expression with audience perception. Further classification of body animations should be further investigated, as an example, hand, legs, eye movement, hips, etc. Investigating age in CG character behavior could also be investigated as a factor that influences perception. Furthermore, the visual appearance of the CG characters were not tested for comfortability and perceived realism. It is clear of the visual appearance could have had any effect or not. We suggest for future studies to test on different CG characters (humanoid and none humanoid). Moreover, participants interacted with one animation in this study. Suggesting a possible bias. We suggest that different animations be used in the future work to avoid this limitation.

In this study, participants removed the headset in order to answer the questionnaire. This method was rather tedious for participants. We would suggest for further studies to integrate the questionnaire within the VR experiment in order to maintain user immersion as suggested by Schwind et al. [11] in their paper regarding presence in VR.

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